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Nationwide Urban Runoff Program
Kansas City Area Project
Executive and Technical Summaries

Mid-America Regional Council, Kansas City, MO

Prepared for

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1. General nature of urban runoff pollutants
2. Relationships between specific land use type and nonpoint source pollutant generation.
3. Pollutant loadings from larger, mixed land use watersheds.
4. Application of NURP results to MARC 208 Plan and MARC Model Grading and Sediment Control Ordinance.
5. Local impacts of urban runoff.
6. Watershed Management Principles and Methods to Reduce Nonpoint Source Pollutants.

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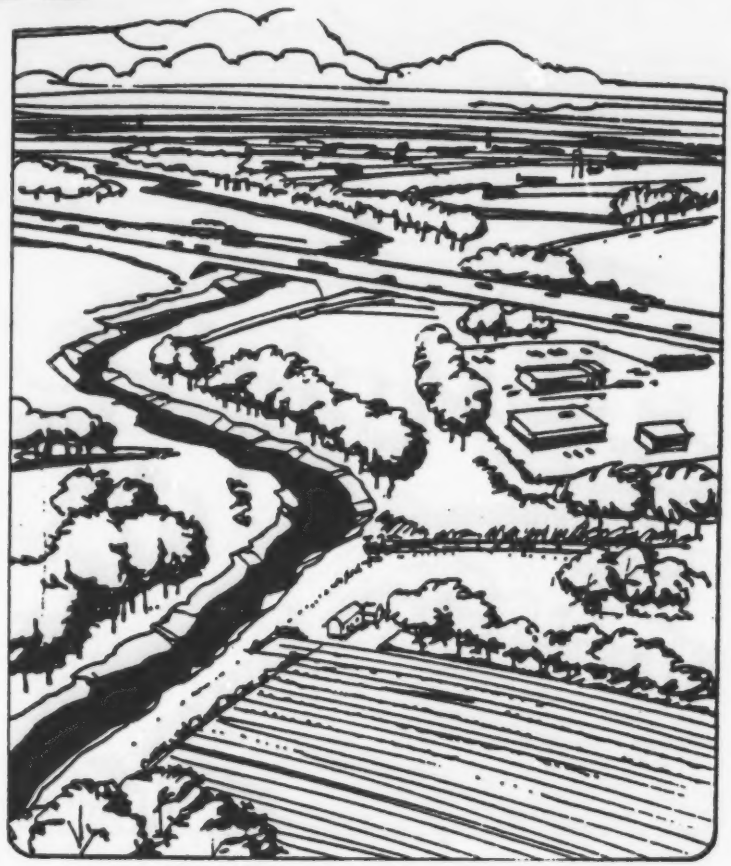

Kansas City Area Project

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EXECUTIVE SUMMARY
and
TECHNICAL SUMMARY

Nationwide Urban Runoff Program

Kansas City Area Project

January, 1983

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EXECUTIVE SUMMARY

Goals

The Kansas City Area Nationwide Urban Runoff Program (NURP) is one of twenty-six Environmental Protection Agency (EPA) projects designed to answer basic questions concerning the quality and characteristics of stormwater runoff from the nation's urban areas. In 1978, the lack of information concerning the amount of pollutants associated with urban runoff became a significant planning obstacle to the goal of nationwide fishable and swimmable waters set by Congress in 1972. A wide scale EPA program was designed to collect information about urban stormwater runoff, and to improve water quality planning and the allocation of pollution control resources. This nationwide effort was integrated with regional and local concerns, producing a multi-use technical program.

In 1979, the Mid-America Regional Council (MARC) began work to develop a NURP project for the Kansas City Area. MARC planned to use the technical information to refine nonpoint pollutant loading estimates contained in the Section 208 Areawide Water Quality Management Plan. (A nonpoint source is a diffuse pollutant source from a wide area, such as from erosion; a point source discharges pollutants from a specific point, such as a sewage treatment plant outfall). MARC incorporated the City of Independence and the Johnson County Unified Wastewater Districts (Johnson County) into the Kansas City Area NURP study to provide local resources for the project and to address specific local concerns regarding urban runoff problems. The City of Independence planned to use the NURP results to provide a city wide stormwater management plan using natural drainage techniques to reduce flooding. Johnson County needed water quality information on Indian Creek during stormwater runoff periods to augment their chemical and biological data base and to increase their understanding of the creek's water quality processes.

Project Design

Two area creeks, one in each of the local participant's jurisdiction, were selected for water quality monitoring. Johnson County provided field crews, laboratory facilities, personnel, and administrative support for the monitoring of Indian Creek in northeastern Johnson County, Kansas. The City of Independence supplied similar services for the monitoring of Rock Creek in western Independence, Missouri.

The two study areas were administered and operated separately. MARC performed the administrative functions of the NURP project, coordinating the different groups and the disbursement of project funds. Public participation activities were also handled by MARC.

The technical consultant, F.X. Browne Associates, Inc., provided the engineering design, participant training, quality control, and day-to-day technical management of the monitoring program. In addition, the analysis of the data, the encoding of the data to EPA requirements, and the preparation of the final report were

performed by the consultant. This summary reviews the project design and discusses the findings from the monitoring data. The technical report provides additional details on monitoring methods and results.

An automated water quality monitoring system was designed to collect and record runoff flow and rainfall data. The monitoring equipment collected stormwater runoff samples according to calculated hydrologic parameters, producing one composite sample representing average runoff water quality during the course of a storm. During the study, over twenty different storm events were sampled ranging from less than .25" to over 3.00" of rain. Other sampling was performed in dry weather and immediately after storms to determine how quickly stream water quality returned to dry weather conditions.

A benthic organism survey was conducted on Indian Creek to examine the effect of the stormwater runoff on the aquatic community. A special toxic pollutant survey was also performed to determine if EPA's priority pollutants were present in Kansas City Area urban runoff.

Two types of monitoring sites were installed in both study areas: land use sites and stream sites. Small catchments (all less than 100 acres) of relatively homogeneous land use were monitored. One commercial and one residential area were studied in both areas. A light industrial catchment was included in the Indian Creek study area.

These land use sites were designed to provide specific pollutant loading data for EPA's nationwide NURP effort. Data from these sites are being used to determine one major unknown in the nonpoint source problem: actual pollutant loadings (usually expressed in pounds/acre/year) that are generated from different types of land uses. Pollutant loading rates for specific land uses can be transferred to other areas with similar land usage and characteristics to estimate pollutant loads. The transferable pollutant loading data can be used by local agencies to analyze unique localized impacts of urban runoff, without the need for extensive (and expensive) site specific monitoring.

For the Kansas City Area study, nine stream monitoring sites were installed on larger natural creeks draining watersheds from 1,372 to 23,942 acres. These sites were selected for local and areawide purposes. In Johnson County, the NURP stream water quality data was to be used to determine the causes of stressed benthic populations and to augment the JCUWD's data base and understanding of the creek's water quality processes. Independence stream monitoring was geared to stormwater management issues such as runoff rates and erosion. MARC planned to use the stream data to verify and refine estimated loadings developed in the MARC Section 208 Areawide Water Quality Management Plan.

Monitoring was performed from June, 1981 to October, 1982. Data was recorded and then entered into the Johnson County Data Services mainframe computer, where a statistical computer package was used for data storage and manipulation. This package was used to encode the data set into the format required for EPA's nationwide computer system. Finally, the data were used with a City of Independence microcomputer to employ statistical techniques for the

characterization of the concentration and pollutant loading data. The effects of hydrologic, geologic, and especially land use factors were the key element in this task.

Results

The findings of the Kansas City Area NURP project are presented in these categories:

1. General nature of urban runoff pollutants
2. Relationships between specific land use type and nonpoint source pollutant generation
3. Pollutant loadings from larger, mixed land use watersheds
4. Application of NURP results to MARC 208 Plan and MARC Model Grading and Sediment Control Ordinance
5. Local impacts of urban runoff
6. Watershed Management Principles and Methods to Reduce Nonpoint Source Pollutants

Summary of Results

General Nature of Runoff

Two main pollution causing processes are activated by runoff: erosion of soil and the washoff of accumulated pollutants on impervious parking lots, streets and roofs. Most pollutants can be produced by either the erosion or the washoff processes, although one process is usually more important. The Kansas City area is particularly vulnerable to impacts from urban erosion because of frequent, high intensity thunderstorms, and the presence of high land slopes in some areas.

Relationships Between Specific Land Use Types and Nonpoint Source Pollutants

Watersheds with high land use intensity, including commercial, industrial, and areas with high traffic volumes, tend to cause high loadings of nitrogen, oxygen demanding substances, and some metals including zinc, copper, and lead. These pollutants accumulate during dry weather and are washed into streams by runoff.

The extent of erosion is determined by secondary land use factors rather than by land use type. Those secondary factors include steep channel slopes in small watersheds and a combination of swale drainage (grassy yard ditches) and high basin slopes. Phosphorus, manganese, iron, and to some extent, nitrogen are associated with the eroded sediment particles.

Pollutant Loadings from Larger Mixed Land Use Watersheds

Large differences in runoff sediment loads between the different basins were observed. Rock Creek drains a completely developed, steep watershed with

predominately swale drainage. The sediment loads from this basin (2.5 tons sediment/acre/year) were about five times higher than the highest loads from less steep, curb and guttered areas (0.5 tons sediment/acre/year). The sediment concentrations in urban runoff were from 20 to 60 times higher than dry weather sediment concentrations. Other pollutant concentrations were usually from 1 to 60 times higher during wet weather compared to dry weather.

Comparison of NURP Data to MARC 208 Plan and MARC Model Grading and Sediment Control Ordinance

The MARC 208 Plan used theoretical relationships and data from other areas to estimate nonpoint source pollutant loads. These planning estimates varied substantially from many of the pollutant loadings monitored by NURP, suggesting that water quality plans requiring relatively accurate nonpoint source loadings should rely on monitoring or use local monitoring data.

The implementation of an erosion control program such as the MARC Model Grading and Sediment Control Ordinance would probably show a significant reduction in urban sediment loads. The NURP data suggests much of the urban erosion occurs in small concentrated areas, such as eroding streams or construction areas. The control of these areas with a performance standard of five tons/acre/year (as suggested by the ordinance) would probably show large reductions in sediment loads to area lakes and streams.

Impacts of Urban Runoff

The NURP data showed that a high level of bacterial contamination is caused by urban runoff and a slight reduction in dissolved oxygen concentrations occurs. The aquatic macroinvertebrate (bottom insects) community in Indian Creek is changing from a nonpolluted water community to a pollution tolerant community in response to urbanization.

Watershed Management Principles

"Hazardous nonpoint source zones," such as areas with high erosion rates or large impervious commercial and industrial developments, are responsible for much of the area's nonpoint source pollutant loadings. This makes the areawide control of nonpoint sources more practical as it is more cost-effective to treat a few concentrated problems than many diffuse problems.

To control erosion related problems from "hazardous nonpoint source zones" several methods are available:

* Implementation of the MARC Model Grading and Sediment Control Ordinance
* Use of stormwater detention basins as sediment traps
* Avoiding the use of swale drainage on high slope areas
* Use of channel stabilization techniques when developing near steep channels

Control of pollutants from impervious areas is more difficult. Street sweeping can remove some pollutants but has a low removal efficiency. Site planning and design to reduce the amount of runoff is the best means to control these pollutants.

TECHNICAL SUMMARY

1. General Nature of Urban Runoff Pollutants

The characterization of urban runoff must include both water quantity and water quality. Urbanization greatly increases the quantity of runoff through increases in impervious areas such as roads, parking lots, and roofs. In addition, construction of curbs, gutters, storm sewers, and other drainage improvements decreases the time it takes runoff to concentrate in streams and creeks. These urbanization factors can greatly increase the extent and frequency of flooding and other stormwater problems.

The urban land surface also provides several sources of pollution for runoff water as it flows to drainageways. Two main pollution causing processes are activated by runoff: erosion of soil and the washoff of accumulated material on impervious surfaces. These two processes create a variety of pollutants in five main water pollutant categories:

Sediment	This general term represents "how muddy the water is" and is defined by the amount of suspended soil material in water.
Nutrients	Phosphorus and nitrogen are found in a number of chemical forms; several of these forms act as fertilizers to aquatic plants and can cause algal blooms and massive aquatic weed growth.
Oxygen Demanding Substances	Organic chemicals remove dissolved oxygen in water when they are decomposed by natural in-stream processes. Many times the organic chemicals are not harmful but the depression of dissolved oxygen in the stream can "suffocate" fish and other aquatic life.
Heavy Metals	These metals include lead, cadmium, copper, and zinc and can cause toxic effects in animal and plant life. Two other examples are iron and manganese, which can cause taste and odor problems in drinking water.
Other pollutants	Coliforms are bacteria found in water and indicate pathogenic microorganisms. Phenols, cyanide, extractable organic chemicals, and volatile organic chemicals are classes of the EPA's 129 priority pollutants.

Most of these pollutants can be produced by either erosion or washoff processes, although one process is usually more important. Sediment pollutant loads from a watershed (the drainage basin) are strongly related to erosion problems. A completely impervious basin (such as a parking lot), however, will produce washoff

sediment loads during a rainstorm because of the accumulation of atmospheric dirt and dust during dry periods. Nutrients are associated with both erosion and washoff, although phosphorus is usually erosion related because it binds easily to sediment. Nitrogen is related to accumulations and washoff of combustion products. Fertilizer application greatly affects nonpoint source nutrient loads. Oxygen demanding substances are produced from erosion and the accumulation and washoff of organic material such as crankcase oil.

Heavy metals related to automobile traffic include lead (from engine exhaust), zinc (from tire wear and motor oil), copper and cadmium. These materials accumulate on and around roads and parking lots. Industrial processes are also sources of these pollutants. Iron and manganese are associated with eroded soil material.

General Impacts of Urban Runoff

Many pollutants have both short term and long term impacts on receiving waters within and downstream of urban areas. Short term impacts are caused by the rapid increase in some pollutant concentrations during runoff periods. Suspended sediment concentrations, for instance, usually increase greatly during wet weather conditions. Long term impacts are caused by nonpoint pollutants transported by urban runoff and deposited in receiving waters. These pollutants settle out and can degrade water quality in dry weather long after the rain stops.

Some of the most common impacts of urban runoff pollutants on receiving waters are: dissolved oxygen depressions; sedimentation in stream channels and lakes; heavy metals toxicity to aquatic plants, insects, and fish; bacterial contamination of contact recreational waters; and eutrophication. Nonpoint source nutrient loadings are very important in the overfertilization, or eutrophication, of lakes, ponds, and reservoirs. Excess nutrients cause algae and aquatic weeds to grow out of control, sometimes covering the lake surface and causing lake oxygen depletion, odors, and skin-irritating algal by-products.

Urban Runoff in the Kansas City Area

The Kansas City Area NURP project examined both the water quantity (hydrologic) and water quality processes in midwest urban runoff. The Kansas City area receives about forty inches of precipitation a year. The intense thunderstorms during the spring and summer can produce very rapid flow increases in urban creeks; an increase in flowrate from 350 cubic feet per second (cfs) of runoff to over 1500 cfs (11,200 gallons per second) was observed in under fifteen minutes from a 37 square mile watershed. The potential for urban flooding has been demonstrated during large, damaging floods in 1977 and 1982.

Exposed soil areas are vulnerable to soil erosion during intense thunderstorms. Over 60% of the annual total erosional energy in rainstorms occurs during June, July, and August. June alone accounts for 30% of the annual total. The Kansas City area is more erosion prone due to intense thunderstorms than about 75% of

the continental United States; only 25% of the country to the south and southeast are exposed to higher rainfall energy during an average year.

Increased reliance on the automobile and construction of additional impervious areas in the Kansas City area have resulted in increased pollutants from the accumulation/washoff process. Large shopping malls and industrial parks have contributed to this trend.

The NURP project examined both the washoff process and erosion in the Kansas City area. This information can be used by water quality planners in the region to estimate urban nonpoint pollutant loadings and the subsequent impacts of these loads on receiving water. The use of actual monitoring data will provide a more accurate tool than values derived from cities outside the midwest or from theoretical relationships.

2. Relationships Between Specific Land Use Types and Nonpoint Source Loads

Five specific land use types were monitored and compared·

* Medium density residential with curb and gutter drainage, medium basin slopes, and a concrete stream channel (Station IR).
* Medium density residential with swale (grass ditch) drainage, steep slopes, and a natural stream channel (Station RR).
* Shopping mall-parking lot commercial area (Station IC).
* Strip commercial area mixed with residential homes (Station RC).
* Light industrial park area (Station II).

All these watersheds were less than 100 acres in area.

Results

1. The amount of runoff from a land use type was determined to be the most important factor in the generation of nonpoint source pollutant loads. Although the highly impervious shopping mall (93% impervious) and industrial site (44% impervious) usually had the lowest pollutant concentrations (and the clearest water samples), the amount of runoff from these sites produced very high pollutant loads. About 50% of the annual rainfall on these sites becomes runoff while the percentages for the other less impervious sites were less than 10% (the rest evaporates or soaks in the ground). The high runoff amount from large impervious areas makes these areas large sources of many pollutants associated with the accumulation/washoff process (see below).

2. Several of the pollutant parameters were related to the intensity of the land use. Nitrogen and oxygen demanding substances were highest from the shopping mall and industrial park, as were several of the heavy metals (zinc and copper, and lead when it was detected). Limited data suggest the metals were almost always greater than 85% recoverable, and were generally

found in the dissolved phase, rather than being attached to sediments, at these sites.

3. High sediment loads caused by erosion were found at the residential area with steep slopes and swale drainage. The monitoring data from this site and the other sites suggests that secondary land use factors are more important in causing erosion than the intensity of the land use. Comparison of the two residential areas showed that the swaled area had the highest annual sediment load of the five sites and was 40 times higher than the curb and guttered area (which had the lowest annual load). The controlling secondary land use features include a high stream channel slope and the combination of swales and high basin slope. The soil type and slope determine if a swale will erode and cause high sediment loads.

4. Several pollutants were found associated with high sediment loads: phosphorus, iron, and manganese. Total phosphorus loads from the swaled residential area were extremely high while the small amount of dissolved phosphorus was relatively close to the other residential site.

5. The effects of fertilizer application were observed at one residential site. During one fall storm, nutrient concentrations were five to ten times higher than previous storm values. The effect of this fertilizer application period appeared to cause higher annual nitrogen loads at this site compared to the other residential site.

Summary

Basins with high land use intensity, including commercial, industrial, and areas with high traffic volumes tend to cause high loadings of nitrogen, oxygen demanding substances, and some metals (zinc, copper and lead). These sites show relatively low pollutant concentrations but high runoff and rainfall ratios. The extent of erosion is determined by secondary land use factors such as the presence of eroding swales and steep channel and basin slopes. Phosphorus, manganese, and iron are generally found attached to sediment particles. Stormwater detention facilities which are designed to settle out urban runoff pollutants would have higher removal efficiencies for sediment related pollutants. They would also be more successful at controlling pollutants from eroding basins than large impervious areas where much of the loading is in the soluble phase.

3. Loadings from Larger, Mixed Land Use Watersheds

Nine larger basins (ranging from 1,372 acres to 23,941 acres) were monitored. The land use ranged from a 50% developed basin with 22% agricultural use to an 82% developed, mostly residential area. Commercial areas in the watersheds ranged from 3-20% of total area and industrial areas ranged from 2-15%. The percentage residential area varied from 45% to 75%. The nine watersheds represented a mixture of drainage type, basin slope, channel slope and other geographic and geologic factors.

Results

1. Large differences in sediment loads were observed between the basins. Rock Creek drains a completely developed, steep watershed with less than 2% curb and guttered streets. The sediment loads from this basin (2.5 tons/acre/yr) were about five times higher than loads from less steep, curb and guttered areas (0.5 tons/acre/yr). A mixed urban-agricultural area produced twice as much sediment as downstream urban areas; sediment loads per acre declined as the percentage of developed land increased and agricultural land decreased.

2. Urban runoff increased stream pollutant concentrations significantly over dry weather values, even for streams where sewage treatment plant effluent dominates dry weather conditions.

Magnitude of Increase of Urban Runoff Stream Concentrations
Over Dry Weather Stream Conditions

Pollutant Parameter	Normal Stream	Stream with Effluent
Sediment	30 - 60 times	20 - 40 times
Nutrients	1 - 7 times	0.5 - 2 times
Oxygen Demanding Substances	1 - 6 times	1 - 2 times
Heavy Metals	1 - 25 times	1 - 60 times

The increase in heavy metals concentrations during wet weather were most evident with iron, manganese, and copper in general, zinc in Indian Creek, and lead in Rock Creek. Urban runoff nutrient concentrations in the streams were sometimes lower than the effluent dominated stream during dry weather periods. This is due more to the high nutrient concentrations found in sewage than low urban runoff concentrations for this watershed.

Nitrogen concentrations generally did not increase during runoff periods. The chemical forms of the nitrogen did change, however, as a larger percentage of the biologically available ammonia-nitrogen and nitrate-nitrogen and less of the organic nitrogen was observed downstream of urban areas.

3. Several parameters were compared against water quality standards and recommended criteria. These standards and criteria were designed for dry weather periods and are not appropriate for a conclusive comparison against wet weather data. The comparison is useful to compare wet weather and dry weather water quality, however, and was performed for several pollutants.

Pollutant Parameter	Water Quality Standard or Criteria	Percentage Samples Exceeding Criteria Dry Weather	Wet Weather	
Fecal Coliform	2000 colonies/100 ml	0-25%	60-100%	
Ammonia-nitrogen	.15 mg/l	40-100%	25-100%	
Phosphorus	.1 mg/l	100%	100%	Rock Creek
Lead	50 µg/l	0%	67-100%	Indian Creek
Iron	1.0 µg/l	0-30%	80-100%	
Manganese	50 µg/l	100%	80-100%	

The frequency of exceedence during wet or dry weather can be used to estimate the annual frequency. For example, roughly 10% of the time Rock Creek is dominated by urban runoff (15% for Indian Creek). If the lead criteria is exceeded 75% of the time during wet weather in Rock Creek, then on the average the criteria is exceeded 7.5% of the time for both wet and dry periods.

4. Sewage treatment plant effluent pollutant loadings can show false nonpoint source loads due to settling. About 20% of the annual phosphorus loads from a 2.5 MGD Indian Creek sewage plant were calculated to settle out downstream of the outfall. This bottom load is probably scoured away during large storms and produced receiving water impacts similar to a nonpoint source load. The phosphorus that settles out represents around 15% of the annual load from the larger 23,941 acre basin downstream.

5. Mass balance calculations compared the wet weather nonpoint source loads with other pollutant sources in the large watersheds. The mass balance was performed for an urban stream with no point sources (Rock Creek, 5566 acres) and one with a point source load (Indian Creek, 23,491 acres).

Pollutant Parameter	Approximate Percentage of Annual Loads From Urban Runoff (%) Stream with Point Source	Stream without Point Source
Sediment	> 98	> 99
Nutrients		
Nitrogen	61	86
Phosphorus	32	97
Oxygen Demanding Substances	86	96

Treatment Plant Flow: about 2.5 MGD

4. Application of NURP Results to MARC 208 Plan and MARC Model Grading and Sediment Control Ordinance

MARC 208 Plan

Two types of comparisons were made between the NURP data and the MARC 208 areawide water quality plan loadings calculated from generalized loading equations. First, specific land use type loading were compared for several parameters. Second, the MARC 208 Plan loads were used to calculate pollutant loads from larger, mixed land use basins.

Results

1. The MARC 208 Plan specific land use loads were generally higher than the NURP monitored loadings. The 208 Plan industrial area loadings were 6.5 times the load monitored at the NURP light industrial site. Half of the 208 Plan loadings for other parameters and land uses were twice as high as their corresponding NURP loads. Commercial site loadings matched better than other land uses.

2. The 208 Plan loadings were applied to three larger mixed land use basins. The plan overpredicted sediment loads from two Indian Creek watersheds by more than 250%. It predicted loads more closely from the steep and erosion prone Rock Creek watershed, where loads were underpredicted by 40%.

   For the other parameters, the 208 Plan was very accurate in predicting loads from a smaller, mostly curbed and guttered residential area in a moderately sloped area. This accuracy was found even though the 208 Plan based the calculation of these factors on the predicted sediment load, which is 250% too high. This suggests the 208 Plan calculation techniques do not reflect the actual ratios of sediment to other pollutants found by the NURP study. The 208 Plan method does seem to predict these more stable parameters better than for sediment despite this inconsistency.

MARC Model Grading and Sediment Control Ordinance

The mass balance calculation between the NURP land use type data and the monitored large watershed loads suggests that a large fraction of nonpoint sediment loads originates from small "hazardous nonpoint source" zones. This term describes urban areas with high erosion rates, such as gullies, channel erosion, pockets of agriculture, poorly maintained land, or construction sites. A calculation was performed assuming that areas under construction were responsible for sediment loads not accounted for in this mass balance calculation. This was done because the acres of construction area were available, and the calculation allowed the estimation of an erosion control program's potential impact.

The MARC Model Grading and Sediment Control Ordinance performance standard of five tons/acre/year of sediment was used as an erosion limit for the estimated

construction loads. The loading calculation was performed again and showed large reductions in annual sediment load, ranging from 20% to over 50%.

Although this case study represents a rough calculation based on several unverified assumptions, the data do indicate that small "hazardous nonpoint source zones" in urban areas are responsible for large fractions of nonpoint source loads. The implementation of an erosion control program, such as the MARC Model Gading and Sediment Control Ordinance, would probably have a significant effect on reducing sediment reaching urban streams and lakes.

5. Local Impacts of Urban Runoff

The National EPA objectives focused on determining the magnitude and characteristics of urban runoff pollutant loadings rather than local water quality impacts. The local elements of the Kansas City area NURP project design did show the effects of urban runoff in the two local streams, however.

Urban runoff produces a dissolved oxygen depression during storm events. No specific correlation between oxygen demanding substances and oxygen depletion were observed, but the depletion usually was less than 1-2 mg/l. The monitoring stations more heavily impacted by urban runoff showed a larger oxygen depletion.

Area urban runoff in general was found to be nitrogen limited, with phosphorus to nitrogen ratios between 1:1 to 1:3, which is lower than the 1:7 ratio found in aquatic plant tissue. A lake influenced by this type of runoff would be controlled by nitrogen loads (nitrogen limited) rather than phosphorus loads. To reduce aquatic plant growth and lake eutrophication, nitrogen loads would need to be reduced.

Bottom dwelling insects (benthic macroinverterates) were collected at 10 stations in Indian Creek, including three stations also monitored for runoff water quality. The goals of this monitoring effort were: to assess the water quality of Indian Creek as reflected by pollutant effects on the benthos; to assess the effects of the point source discharge versus the effects of nonpoint source urban runoff on the benthos; and to determine if a pollutant tolerant type of benthic community develops as the drainage basin becomes urbanized. This monitoring program resulted in the detection of several trends:

1. The major influence on the benthos in the unurbanized portion of Indian Creek is the wastewater effluent.

2. The benthic community is shifting from being dominated by fairly clean water organisms typically found in local unpolluted streams to a dominance of more pollutant tolerant organisms that are capable of surviving under stressed conditions.

3. This community shift corresponds to increased urbanization of the basin and has been accompanied by lower species diversity, lower biomass and lower numbers of taxa.

6. Watershed Management Principles and Methods to Reduce Nonpoint Source Pollutants

Nonpoint source pollutants are produced by two main processes: erosion of exposed soil and the washoff of accumulated matter on impervious surfaces. A specific pollutant is usually associated more with one of these two processes than the other. The Kansas City area NURP results indicate that the main sources of urban runoff pollutants are relatively small, scattered areas where erosion is very bad or large concrete and impervious areas are located. A pollutant control program should focus on controlling these "hazardous nonpoint source zones" and should reflect the type of pollutant generation process occurring in each zone.

Erosion-related Pollutants

Serious erosion problems contribute large loadings of sediment, phosphorus, iron, and manganese (and nitrogen to a lesser extent) to waters receiving urban runoff. The main factors related to erosion in urban areas (excluding construction areas) are stream channel erosion and swale drainage (grassy ditches usually used in residential areas) in watersheds with high basin slopes.

Channel erosions correlated strongly with high channel slopes in small watersheds (less than one square mile). These watersheds are in relatively steep areas near ridgelines and are drained by narrow ravines with steep sidewalls and steep bottom slopes. High runoff velocities from urban developments tear away the sidewalls to form a larger channel for the post-development flows.

Larger watersheds (over 1,000 acres) showed less of a relationship between erosion and channel slope. Larger streams flow down relatively flat floodplains that have slower runoff velocities. However, the percentage of agricultural activity in larger watersheds was a good indicator of sediment loads.

Both large and small watersheds show a strong relationship between erosion and the amount of swale drainage occurring on steep slopes. A mixed commercial and residential area with 50% swale drainage had one tenth as much erosion per acre as a swale drained residential site less than two miles away. The soil types were similar; one main difference was in basin slope, where the high erosion site had a 5.5% watershed slope compared to 2.5% for the low erosion site. The combination of high slopes and swale drainage probably creates many "hazardous nonpoint source zones" in the Kansas City area.

Although a construction site was not monitored during the NURP project, other studies have shown that construction related sediment loads are usually many times higher than even the highest sediment load measured in the NURP study. Land clearing and grading during construction represent another common "hazardous nonpoint source zone" which add large amounts of sediment and associated pollutants to area streams and lakes.

Control of Erosion Problems

An erosion control plan to reduce erosion from these "hazardous nonpoint source zones" would probably significantly reduce nonpoint source pollutant loads. One calculation using NURP data suggests that large reductions in annual urban sediment loads are possible if an erosion control program such as the MARC Model Grading and Sediment Control Ordinance is implemented. Although the NURP calculation provided only a rough estimate of erosion reductions, the data does support the conclusion that many of the area's sediment problems originate from a few problem areas. Erosion control in a few "hazardous" areas is much easier to implement than in many widespread areas.

The MARC Model Ordinance is one method of implementing the type of erosion control program that has been successful in other areas, such as the states of Maryland and Virginia. Inexpensive and proven erosion control technology is detailed in the MARC Model Ordinance and includes:

* Water diversions away from exposed soil
* Grade stabilization devices
* Grass waterway design criteria
* Mulching
* Sedimentation Basins

Some erosion problems can also be reduced by designing stormwater detention facilities (or redesign existing facilities) to double as sedimentation basins. Many inexpensive methods are available to install risers on discharge structures to allow sedimentation in the basin. This approach requires periodic removal of the accumulated sediment, however, and is actually treating the product of an erosion problem rather than the actual source of the problem upstream. One good application for developments incorporating stormwater detention facilities is to build them before most of the site grading and use them as temporary sedimentation basins to trap high construction pollutant loads.

Proper planning of development can greatly reduce the amount of erosion occurring in urban areas. Some guidelines for avoiding erosion problems are:

* Areas with steep natural channels (usually near ridgelines) are very susceptible to increases in runoff. Development in those areas should put special emphasis on reducing post-development runoff and on installing channel stabilization devices.
* Erosion prone areas (erodable soils on steep slopes) should be developed using curb and gutter drainage with storm sewers and avoid swale drainage. The Soil Conservation Service can provide soil maps and information concerning erodable soils. Areas with very high erosion potential should not be developed or be developed with a low intensity land use.
* If possible, plan site clearing and grading during construction for periods of less erosive rainfalls. The month of June produces the most erosive conditions with high intensity rains and wet soils.

Pollutants from Impervious Areas

Pollutants such as nitrogen, oxygen demanding substances, zinc, copper, and lead are associated with the washoff of accumulated pollutants from parking lots, roofs, sidewalks, and other impervious areas. The intensity of land use was the most important factor related to these pollutants, although rain intensity and the number of dry days pollutant accumulation were also correlated to loads. Industrial areas generally produce the highest loads per acre of these washoff pollutants, and large, completely impervious commercial areas have the next highest loads. A half developed light industrial area had higher loads than a large shopping mall; completely developed heavy industrial areas would show even higher washoff loadings. The NURP data showed that the light industrial and shopping mall almost always had two to five times the washoff related pollutant loads from a given storm as a residential site with little erosion, and were almost always higher than a residential site with high erosion.

Control of these pollutants is more difficult than erosion related pollutants. Street sweeping is one means of removing some of accumulated pollutants from concrete surfaces. However, several other NURP studies have concluded that street sweeping has relatively low pollutant removal efficiencies except in dry regions. Frequent street sweeping is necessary to significantly reduce the pollutant loadings.

The removal of these pollutants from runoff is more difficult compared to erosion related pollutants. Sedimentation is less successful because more of these pollutants are in the soluble phase.

Planning of these developments can minimize their water quality effect. These high intensity developments, especially large malls or industrial complexes, should be located away from sensitive water quality areas. To reduce the impact of commercial and industrial complexes, the drainage design should minimize the amount of runoff that is generated. Innovative drainage techniques such as grassy areas to soak up runoff, gravel infiltration pits, or swale drainage (with proper slope conditions) can be applied to reduce pollutant export.

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